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UNITED STATES
DEPARTMENT OF THE INTERIOR
J. A. KRUG, SECRETARY

BUREAU OF MINES
JAMES BOYD, DIRECTOR

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SUPPORT OF GROUND, IRON-ORE MINES, LAKE SUPERIOR DISTRICT

BY

MAX S. PETERSEN AND FRANK E. CASH

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By Max S. Petersen[2] and Frank E. Cash[3]

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INTRODUCTION

Falls of ground cause the greatest number of accidents at underground metal mines. Statistics compiled by the Federal Bureau of Mines show that during a 13-year period ended in 1943, falls of ground caused 35 percent of the fatalities and 16.8 percent of the nonfatal injuries at underground metal mines in the United States.[4/] Expressed on a basis of a million man-hours worked, the frequency rate was 0.355 for fatalities and 11.76 for nonfatal injuries. Although some progress has been made in preventing rock-fall accidents over a 30- or 40-year period, the problem is still a major one requiring the diligent efforts of management and employees.

In the Lake Superior district, where organized safety programs have been in effect for more than 30 years, the record is more favorable. Statistics compiled by the Lake Superior Mining Section of the National Safety Council reveal that over a 6-year period ended in 1945 the frequency rate of fatalities per million man-hours was 0.277, and the rate for nonfatal injuries was 2.38 from falls of ground.

Although the above-given statistics do not cover equal or concurrent periods, the improvement in accident experience in the Lake Superior district over the national average, is obvious. This improvement is due to more effective methods of ground support or more rigid enforcement of the use of known methods.

It is hoped that the following information about ground-support practices in the Lake Superior district will assist operators of other mines in their efforts to reduce accidents from falls of ground.

SCOPE

This report describes ground-support practices at 13 of the 44 active underground iron-ore mines in the Lake Superior district. The 13 mines supply one-third of the total tonnage produced from underground mines and operated by 5 of the major operating companies that produce over 80 percent of the iron ore from the district. The mines were selected to give an average cross section of companies, ranges, mining methods, ground conditions, and other variables.

ACKNOWLEDGMENTS

It would have been impossible to preface this report without the cooperation of the mining companies through their officials and employees, in permitting their properties to be visited and in furnishing data on their operations and practices.

The authors acknowledge this cooperation from the following companies:

The Cleveland-Cliffs Iron Co.
The M. A. Hanna Co.
Inland Steel Co.

4/ Bureau of Mines, Accidents from Falls of Rock or Ore in Metal Mines. Metal-Mine Accident-Prevention Course-Section 2: Miners Circ. 52, 1944, p. 4.

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Oglebay, Norton & Co.
Oliver Iron Mining Co.
Pickands, Mather & Co.

Information from Bureau of Mines publications and other scientific articles has been drawn on freely. The references and footnotes will assist in obtaining additional details.

GENERAL INFORMATION

Iron ore is produced in six major districts, called "ranges", in the Lake Superior region - the Vermilion, Mesabi, and Cuyuna in Minnesota, the Gogebic in Michigan and Wisconsin, and the Menominee and Marquette in Michigan.

On the Vermilion range ore occurs in a gently pitching syncline or trough, with steeply dipping limbs. The wall rock is generally greenstone. The ore varies from a soft sticky mass to a dense, hard material that is almost as tough as steel. The ore is mined entirely by underground methods, the principal of which are: Top slicing, sublevel caving, and cut-and-fill stoping.

On the Mesabi range ore occurs in relatively shallow widespread ore bodies, which lend themselves to open-cut mining. On the margins of these bodies small lenses extend out, which must be mined by underground methods. Top slicing (or merely "slicing" where the ore body is one "sub" thick) is almost universally employed. The ore is soft; and, although the hanging wall must be supported, the weight is not excessive.

Ore occurs on the Cuyuna range in a closely folded formation having many ore bodies near the surface, which are mined by open-cut methods. The ore bodies on the limbs of deeper folds are mined by underground methods - top slicing being generally employed. The ore is soft to medium hard, and the walls are greenstone or lean ore.

On the Gogebic range, ore occurs in V-shaped troughs formed by the intersection of dykes with a steeply dipping iron formation that is relatively regular in strike and dip. One ore body is shallow enough to permit open-cut mining, but the others are relatively deep. The ore is soft to medium hard; the hanging wall is generally a cherty or slaty iron formation, which breaks into blocks or slabs that create a condition necessary to successful sublevel caving, which is the general practice.

The Menominee range is in a highly folded iron formation, and ore occurs on the limbs of major folds or often occupies the entire trough of a minor fold. The hanging wall is generally strong enough to permit open stoping where ore bodies are located in steeply pitching beds. An interbedded black slate, high in sulfides and quite combustible upon exposure to air, complicates mining where the slate occurs adjacent to or near the ore.

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The Marquette range ore bodies occur in minor folds of a wide westward-pitching synclinorium. The iron formation consists of ferruginous cherts and slates intruded by dykes and sills. The hanging wall is usually jasper or ferruginous chert, which is hard but quite friable and when caved breaks into medium-size pieces. The predominant stoping method is top slicing, although some open stoping is practiced where wall conditions permit.

A summary of the tonnage produced by the principal mining methods is given in table 1. For purposes of the table, the tonnage from producing mines was classified according to the principal mining methods used, and the percentages are therefore approximate.

TABLE 1. - Percent of ore produced by various mining methods

Annual average production, 1936-45	Range	Open-cut	Open stopes 1/	Sublevel caving	Top slicing	Total (percent)
1,436,000	Vermilion	0	15 2/	37	48	100
47,905,000	Mesabi	97	0	0	3	100
1,914,000	Cuyuna	91.5	0	0	8.5	100
Total	Minnesota	94.5	.4	.8	4.3	100
5,130,000	Gogebic	0	0 3/	100	0	100
3,387,000	Menominee	0	77 2/	23	0	100
4,978,000	Marquette	12	16	8	64	100
Total Michigan-Wisconsin		4	28	45	23	100

Note: Percentages given in table are approximate due to classification of mines according to principal mining method.

1/ Includes sublevel stoping, cut-and-fill stoping, and open stopes with pillars.

2/ Cut-and-fill stoping.

3/ Principally sublevel stoping.

FUNDAMENTALS OF GROUND SUPPORT

Support of ground involves at least two general aspects: (1) The selection of a suitable mining method and its intelligent application to prevent major ground movements and cave-ins, and (2) the support of mine openings to prevent local caving from the immediate backs. The first type of caving is a continuation or extension of the second; thus the important feature of ground support is to prevent the start of caving. Loosening of the immediately overlying rocks is prevented, or at least retarded, when supports, such as timbers are placed in time. Obviously, if the stoping method does not afford adequate support, the timbering of individual workings will not be effective. Similarly, the adoption of a safe stoping method will not solve the problem unless attention is given to details of the support of individual workings.

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The selection of a suitable mining method is the responsibility of management. Factors to be considered in its selection have been enumerated,5/ by the principal consideration, in so far as accidents from falls of ground are concerned, is one of support. The method selected must be capable of supporting the stope opening until the ore is removed.

The bulk of the underground ore in the Lake Superior district is mined by two methods: (1) top slicing and (2) sublevel caving. Both methods are classified as caving methods, wherein mining is conducted under a gob or mat of old timber. Successful mining by either method requires that the overlying rocks cave and follow the mining downward. Sublevel caving is employed where the gob will arch, and hang up long enough to permit removal of the ore from the face of the working slice. This same condition would be hazardous in a top-slicing operation, because a sudden caving of the gob might crush the timbers. For safety in top slicing, the gob must follow mining closely.

The means by which ground is supported may be divided into two types, (1) natural and (2) artificial.

Natural support depends on the strength of the ore and wall rock and their ability to support themselves over certain spans. Pillars are the principal means of natural support where the stope opening exceeds the safe span over which the ore or rock will stand. Arching of the back or sides of openings may also be employed.

Artificial support may be provided by filling, timber, steel, or concrete.

In some instances where the deposit is overlain by water-bearing surface material, the permanent support of the surface may be required to insure the safety of underground workmen. A partial list of inrushes of mud and water, which have occurred in the Lake Superior district since 1893, reveals that 161 persons lost their lives when the support of the pillar between the deposit and the surface material failed. Such accidents are awe-inspiring and receive wide publicity; however, the frequency and severity of these accidents is small compared to accidents caused by the fall of relatively small pieces of ore or rock.

A survey of fatal accidents due to falls of ground reveals that a large majority are caused by pieces weighing 3 tons or less. The prevention of this type of accident requires the support or removal of loose material in the backs and sides of mine openings. This is a day-to-day problem and requires not only effective supporting members, but also close supervision to insure that such supports are placed in time.

Pillars

Three of the mines covered by this report (B, C, and D) utilize pillars as a principal means of ground support.

5/ Jackson, Chas. F., and Gardner, E. D., Stoping Methods and Costs: Bureau of Mines Bull. 390, 1936, pp. 26-40.

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At mine B, on the Marquette range, the ore occurrence is irregular, varying from 25 to 150 feet in thickness, and from flat to 60° in dip. The ore is dense, hard hematite. The hanging wall may be slate, conglomerate, dyke material, jasper, or greenstone. The footwall is jasper, siderite, or greenstone. Where the hanging wall is slate, it slacks on exposure to air, causing rock falls. The dyke material may also be subject to rock falls. Where this condition is known in advance, a small amount of ore is left to protect the wall and prevent falls.

Open stoping is practiced at mine B, with an irregular to checkerboard arrangement of pillars. The level interval is 30 to 50 feet, and the ore is ordinarily stoped underhand. The general procedure of stoping is to drive rooms 25 to 50 feet wide, separated by pillars, usually 25 feet wide. When this system of parallel rooms is completed, the horizontal extent of the ore body is apparent, and the pillars are cut into smaller segments by crosscuts. The average horizontal cross section of pillars is 25 by 25 feet. Stoping then proceeds by mining the ore underhand. Level pillars may or may not be left at each level. Some filling of stopes is done, but the primary purpose is to dispose of development rock.

Permanent support of the surface over mine B is imperative because the mine is beneath a town and a water-bearing overburden. For this reason the number and size of pillars left are "on the safe side". It is estimated that 25 percent of the ore is left in pillars, and most of this is on the upper levels. Experimental work in pillar recovery, using a microseismic recorder to determine the effect on adjacent pillars, is being done.

Mines C and D, on the Menominee range, practice sublevel stoping with a regular arrangement of pillars. The ore is moderately hard hematite and limonite, dipping at relatively steep angles. The wall rock may be a cherty, fairly hard iron formation or black slate, which tends to slough off on exposure to air.

Ore bodies are divided into stopes and pillars after the extent of the ore has been fairly well determined. Pillars on consecutive levels are kept in line vertically. Floor pillars are usually left at each level. The size of stopes varies from 40 to 100 feet wide, 105 to 300 feet long, and 125 to 175 feet high. Stopes may be laid out either along the strike or perpendicular to it, depending upon the width of the ore. Where the ore body is wider than the desired stope width, the stopes usually are laid out across the strike. In some instances a wide stope may be divided into two segments by a vertical, longitudinal pillar about 25 feet wide.

The regular pillars left between stopes vary from 25 to 40 feet in width and extend from level to level. Floor pillars are usually 50 feet thick. Mine D has increased the width of pillars in recent years from 25 to 40 feet and decreased the stope length correspondingly to minimize the crushing of pillars. This became necessary owing to the depth of mining and the large number of mined-out stopes.

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In the original lay-out of stopes, as much as 50 percent of the ore may be left in pillars. Upon completion of the stopes, a considerable portion of this ore is usually recovered by removal of the pillars between the mill sublevel and the scraping drift. If the condition of the stope walls is favorable, an entire pillar between stopes may be removed, or if the stopes are filled, the entire pillar can be removed by top slicing, thereby greatly increasing the total recovery.

Figure 1,A, shows a typical sublevel stope at mine D, and figure 1,B, shows a typical plan and longitudinal section of the stope arrangement at mine C. In each instance a thin scale of ore has been left to protect a black slate wall, which will slough off and fire spontaneously if unsupported.

Filling

The practice of filling stopes is used only to a limited extent in the Lake Superior district.

At mine A the ore is a very hard, dense hematite. On both walls a 5- to 6-foot "softened zone" of chlorite or sericite schist occurs adjacent to the ore. Cut-and-fill stoping is practiced to support the walls and prevent dilution of the ore. Once the ore is removed from the stope, the filling no longer serves any useful purpose, and it may be drawn out to fill stopes below. The ore is stoped in 12-foot horizontal cuts, and filling is introduced to within 7 feet of the back of the stope. Fill raises to the level above are in the footwall at 200-foot intervals. Filling material is either trammed to the raises on the level above or tapped from filled stopes directly above. It is spread in the stope by 48-inch scrapers.

Mine D, on the Menominee range, has been producing ore since 1893 by a sublevel stoping method. In recent years crushing of pillars and caving of stope walls, due to the large area excavated, made filling of mined-out stopes advisable.[6/] Another condition that made filling necessary is the occurrence in the walls of black slate, rich in sulphides, which ignite spontaneously upon exposure to air.

Stope-filling material, consisting of sand, clay, gravel, and hard pan, is secured from surface glacial drift material. It is loaded by power shovel and hauled in trucks to fill raises or churn-drill holes[7/] connecting with mine openings below. As filling material is received on a level, it is either allowed to run directly into open stopes, of is scraped to the top of stopes to be filled. As new stopes below require filling, an opening is made into the filled stope above, and the material is passed through. It is then necessary to refill the uppermost stope.

6/ Koehler, G. A., Sublevel Stoping with Delayed Filling, Hiawatha Mine, Iron River, Mich.: Am. Inst. Min. and Met. Eng., Mining Practice, 1945, pp. 253-261.

7/ Johnson, Ernest W., and Cash, Frank E., Sinking Large-Diameter Drill Holes, Lake Superior District Underground Mines: Bureau of Mines Inf. Circ. 7354, 1946, 21 pp.

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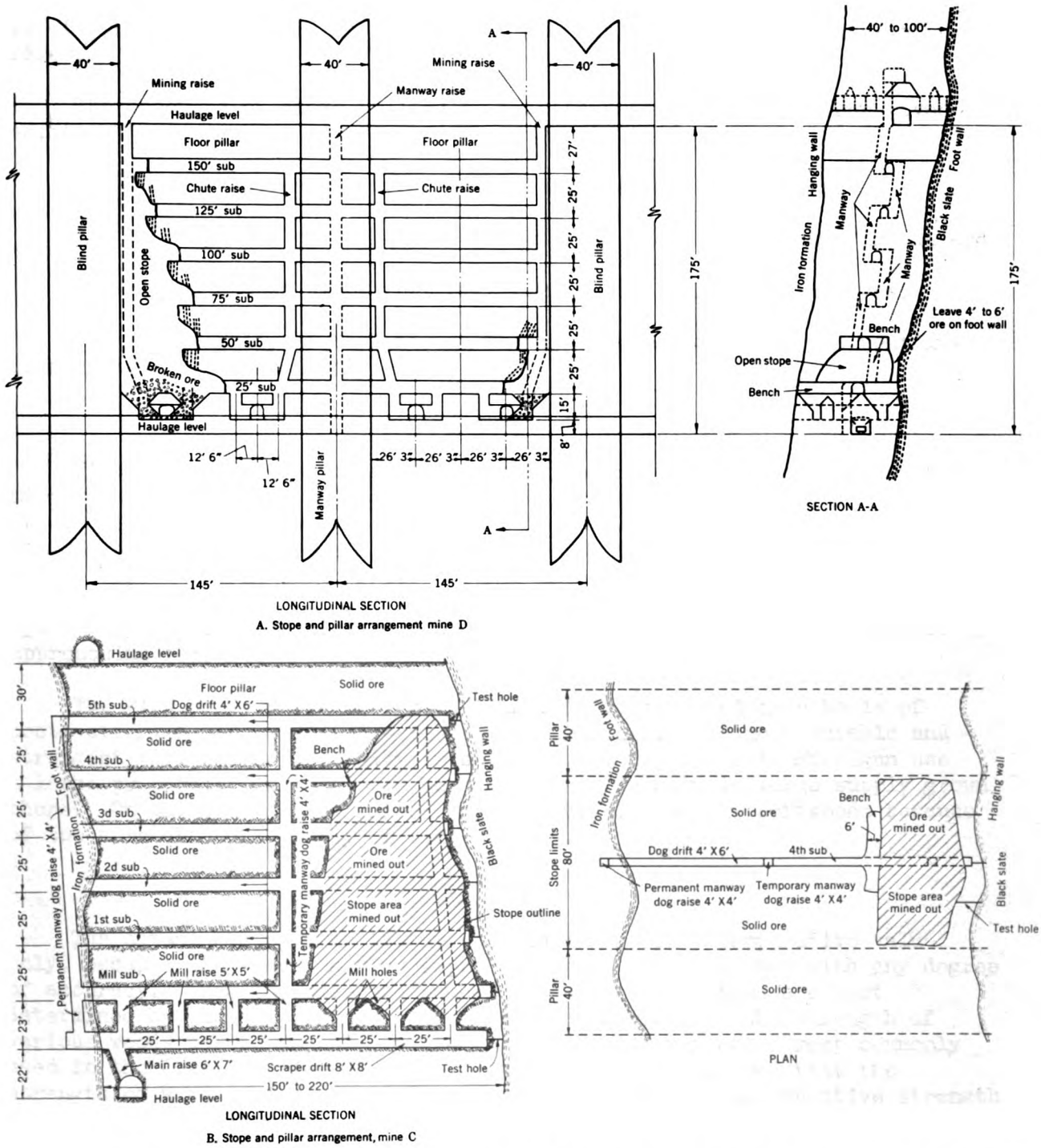

Figure 1. - Typical sublevel stoping, showing layout of stopes and pillars.

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Before filling is introduced into stopes, practically all openings into the stope are sealed with steel and concrete or timber bulkheads. This is of further assistance in sealing off the air and preventing black-slate fires.

The benefits of stope filling as practiced at mine D have been given as:[8]

1. Filling stopes minimizes the crushing effect on pillars.

2. It stops the caving of black slate and the accompanying fire hazard.

3. Filled stopes allow further mining in the pillars themselves.

4. The quantity of foul air in the mine is reduced, and the ventilation systems are more easily controlled.

Timber

Timber is the material most frequently used as artificial support for mine workings. It has relatively great strength, comparing favorable with steel on a weight-for-weight basis. It is easily cut and framed into the desired shapes and sizes and can be trimmed to fit with hand tools if necessary. Unlike steel, which fails quickly once initial deformation has taken place, timber fails gradually under pressures exceeding its strength. The splitting and cracking of timber under a heavy load serve as a warning of approaching failure.

The kind of wood used for mine timbering is selected on a basis of cost, strength, and resistance to decay. Ordinarily the most durable and strongest variety grown locally is selected. Thus, mines in Michigan use a large proportion of hardwoods because of the relatively large supply grown there. On the other hand, Minnesota mines utilize mostly softwoods because of the more abundant supply of that variety.

Strength

The actual strength of timber used in mines is of comparative value only, because the loads on mine supports cannot be calculated with any degree of accuracy. Thus the size and number of supports in mines are best determined by past experience. However, a comparison of the strength of various woods may be useful, and table 2 lists the varieties most commonly used in the Lake Superior district. It should be remembered that the strength of wood varies so widely within a species that the relative strength of timber may be largely a matter of grade. The values listed in the table are based on tests of small, clear specimens.

In general, tamarack is the most desirable of the softwoods; Norway pine has about the same strength as tamarack, but not the resistance to decay.

8/ Work cited in footnote 6.

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All the hardwoods listed, except black ash, are stronger than the softwoods. Yellow birch and sugar maple constitute a large majority of the hardwoods used in the Michigan mines.

TABLE 2. - Comparative strength values of species used for mining timbers[1/]

Name		Comparative strength values[2/]		
Common	Botanical	Bending strength (as a cap)	Compressive strength (as a post)[3/]	Shock resistance (ability to withstand sudden load)
Hardwoods				
Ash, black.....	Fraxinus nigra....	77	68	122
Ash, white.....	Fraxinus Americana	113	106	153
Birch, yellow..	Betula lutea.....	106	98	171
Elm, rock.....	Ulmus yacemosa ...	106	97	189
Maple, black...	Acer nigrum	93	89	135
Maple, sugar...	Acer saccharum ...	114	106	138
Softwoods				
Cedar, northern white.....	Thuja occidentalis	50	52	47
Hemlock, eastern	Tsuga canadensis..	72	79	67
Pine, jack.....	Pinus banksiana...	64	73	78
Pine, Norway...	Pinus resinosa ...	85	91	84
Pine, northern white.....	Pinus strobus.....	63	67	55
Spruce, white..	Picea glauca	68	70	67
Tamarack.....	Larix laricina ...	84	96	85

1/ Abstracted from Tech. Bull. 158, USDA, Comparative Strength Properties of Woods Grown in the United States, by L. J. Markwardt.

2/ The strength figures are not percentages but are index numbers. They have no significance other than to give relative position in comparing species of wood for any specific use with respect to the several properties listed.

3/ Applicable to short columns having a ratio of length to least dimension of all (or less) to 1.

Resistance to decay and cost of timber are treated later in this report.

Specification and Purchase of Timber

Mining timber is almost invariably cut and delivered to the mine by local contractors or jobbers. In some instances the cutting is from timber lands owned by the mines; in other instances the contractor arranges and pays for the stumpage on privately-owned or Government-owned land. Timber is generally cut and delivered in the fall and winter, although these operations may extend throughout the entire year. Where peeling of timber is required, this operation is accomplished most easily in the spring. The time of cutting has little effect on the strength of timber, provided (and this is important) proper storage is provided.

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THE IRON CO.

Mine Timber Specifications

CRIBBING TIMBER

TAMARACK—

(a) This timber must be straight, sound and green.
(b) Top diameters—6" to 9".
(c) Lengths—5'4", 10'8" or 16', as specified.
(d) No rot of any kind permitted.
(e) This material must be shipped in individual cars.

STULL TIMBER

HARD AND SOFT MAPLE, YELLOW BIRCH, TAMARACK AND HEMLOCK—

(a) This material must be straight, sound and green.
(b) White Birch, Poplar, Ash, Balm of Gilead, Balsam or Jack Pine will not be accepted.
(c) No hemlock under 10" tops accepted.
(d) In top diameters from 9" to 14", one 6" sweep in 16' and 18' lengths will be permissible, providing sweep runs from top to butt of log.
(e) In top diameters from 9" to 14", one 3" sweep in 8' and 9' lengths will be permissible, providing sweep runs from top to butt of log.
(f) Logs containing dry rot, doze, shake, sap rot or hollow butts will not be accepted.
(g) Knots, burls, limbs, etc., must be trimmed to surface of log.
(h) In top diameters 9" to 14", cut all timber in lengths of 9' and 18', unless otherwise specified.
(i) All timber to be scaled inside bark at top end in inches with standard scale rule.
(j) Not over 20% hemlock accepted.

LAGGING

7' LAGGING—

(a) 128 cubic feet per cord or by lineal feet.
(b) Straight, sound, cedar, tamarack and spruce.
(c) Round, 3" to 4½" tops, unless otherwise specified, larger than 4½" to be split. Split not less than 2½"x4" nor larger than 3"x6" tops.
(d) Not over 50% split cedar.

POLES

9½' POLES—

(a) 3½" to 6" tops.
(b) Must be straight, sound and green tamarack.
(c) Nothing under 3½" tops accepted.

19' POLES—

(a) 3½" to 6" tops.
(b) Must be straight, sound and green tamarack.
(c) Nothing under 3½" tops accepted.

GENERAL

(a) Material not in accordance with above specifications will be rejected.
(b) Mine scale to govern.
(c) Cars must be tagged showing shipper, destination and tally on car. As soon as cars are shipped, forward bill of lading to IRON CO., MINE TIMBER DEPARTMENT, MICHIGAN."
(d) Cars must be loaded to maximum capacity allowed by railroad. When cars are underloaded, shipper pays difference between actual and minimum weight.
(e) Whenever possible to load more than one car within 48 hours and when two or more cars are loaded at one siding and taken out by train crew, all cars to be covered by one bill of lading.
(f) No payment will be made for timber until bill of lading covering shipment is received by Mine Timber Department.
(g) Stull timber (9" and up) must be loaded on flat cars. Cribbing timber can be loaded on either flat cars or gondolas.

FOR FURTHER INFORMATION AND PRICES WRITE THE IRON CO., MINE TIMBER DEPARTMENT, MICHIGAN.

Figure 2. - Mine timber specifications.

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Specifications as to variety, sizes, imperfections, and other limiting conditions are drawn up by the timber-purchasing department for the guidance of contractors. Figure 2 is a copy of the timber specifications currently used by one company.

Table 3 lists the sizes of timber purchased by 10 of the mines visited.

Storage

The amount of timber in storage at Lake Superior iron-ore mines ranges from a 2-month to a 2-year supply. Where conditions require the use of green poles, such as poles used for spiling, frequent deliveries are made and a small supply is kept on hand. Where seasoning is necessary, as in timber treatment, purchases are ordinarily made 1 to 2 years in advance.

TABLE 3. - Size of timber purchased

	For sets							
	Main levels		Slices		Poles		Cribbing	
Mine	Diam.	Length	Diam.	Length	Diam.	Length	Diam.	Length
A	12"-16"	6' & 7'	-	-	4"-6"	12' & 16'	10"-12"	6' & 7"
E	Over 12"	8'	8"-12"	8'	4"-6" 5"-6"	9' 14'	Average 6"	4' & 5'
F	11"-13"	8'	9"-11"1/	8'	4"-5"	8'	5"-7"	5'
G	11"-15"	8' & 9'	9"-13"	7'	4"-6"	5-6 1/2' & 8'	5 1/2"-7 1/2"	4 1/2'-8'
H	9"-15"	8'-9' & 12'	9"-15"	8'	3"-5"	16'	6"-9"	5'4"
I	8"-14"	9'	8"-14"	9'	3"-9"	9'4"	5"-10"	5'4"
J	5"-12"	10'	5"-12"	10'-20'	4"-6"	8' & 12'	-	-
K	8"-12"	10'	9"-13"	12' & 14'	3"-6"	12'	6"-7"	6'
L	9"-14"	9'	9"-14"	9'	3 1/2"-6"	9 1/2'	6"-8"	5'4"
M	10"-13"	9'	10"-13"	9'	3 1/2"-6"	9 1/2'	6"-9"	5'4"

1/ Used for lining sets and repairs.

Timber received at the mine is stored in open yards near the shaft through which it is to be lowered into the mine. Timber skids are usually provided, and timber is closely piled on these. If the timber is used within a short time, this practice may not be too undesirable, but if it is allowed to remain in this condition for an extended period, deterioration will reduce the serviceable life appreciably. Some improvement in storage conditions could be effected at Lake Superior iron-ore mines.

Good storage facilities require the timber yard to be on a well-drained location, preferable on a gentle slope. Ditches should be provided to deflect

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heavy run-off surface waters from the site. The ground should be free from debris and decaying organic material. Weeds should be cut or kept down with a covering of crushed rock or cinders. Timber should be piled on skids to keep it well off the ground, and the piles should be open so air can circulate around each stick. This can be best accomplished by using cross pieces between each layer.

Framing

The practice of framing timbers on the surface or at the face in the underground workings is about equally divided. Each practice has its advantages. Where sets are framed on the surface, a better selection of the stronger pieces to be used as caps is possible. Culls may also be sorted out, whereas if the three pieces constituting a set are delivered to a mining face, and one is defective, in all probability it will be put into place. Some companies prohibit the use of certain varieties of wood as caps, but will permit the same variety to be used as a post. This is more easily and correctly determined on the surface by men more familiar with timber than the average miner. In addition, a better job of framing will be done by experienced timbermen. Where framing is done at the working face, this operation will not, in most cases, prevent the men from accomplishing their daily task of drilling, blasting, scraping, and timbering one set.

At some mines framing is done on the surface under contract on a basis of a unit price per piece. Other mines require a minimum number of pieces to be framed by two men each shift. Framing under contract requires considerable inspection to prevent slipshod work.

Caps and posts are framed with hand tools - in most cases a crosscut saw and ax, or adz. One mine uses a two-man, chain-type portable power saw to make the crosscuts, finighing the framing with an adz. It was observed that use of this saw made the men inclined to cut the joggles or daps too deep. The use of elaborate framing equipment, such as that used to frame square-set timbers, is not practiced, because of the additional labor of handling.

Posts and caps are framed in several designs, as illustrated in figure 3. In some instances (A) the posts are cut square, all the bevel being on the cap. In others (B) the posts are cut on a bevel and the cap joggle framed out parallel to the length. In still other instances (C), the bevel is divided between the post and the cap. Where considerable batter is required on a post, the strength of the cap is reduced if all the bevel is cut on it, and the best practice is to cut the post on a bevel.

One mine does not cut a joggle on the posts (D). Under ordinary circumstances this practice may not be undesirable; but if the load on such a set approaches the ultimate strength of the timber, initial failure will be a splitting of the cap at the base of the joggle. Similar failure has been observed where framing was careless, leaving a space between the bottom of the cap and the joggle in the post. One mine uses a template as a guide for the timber framers in cutting the proper angle on the posts.

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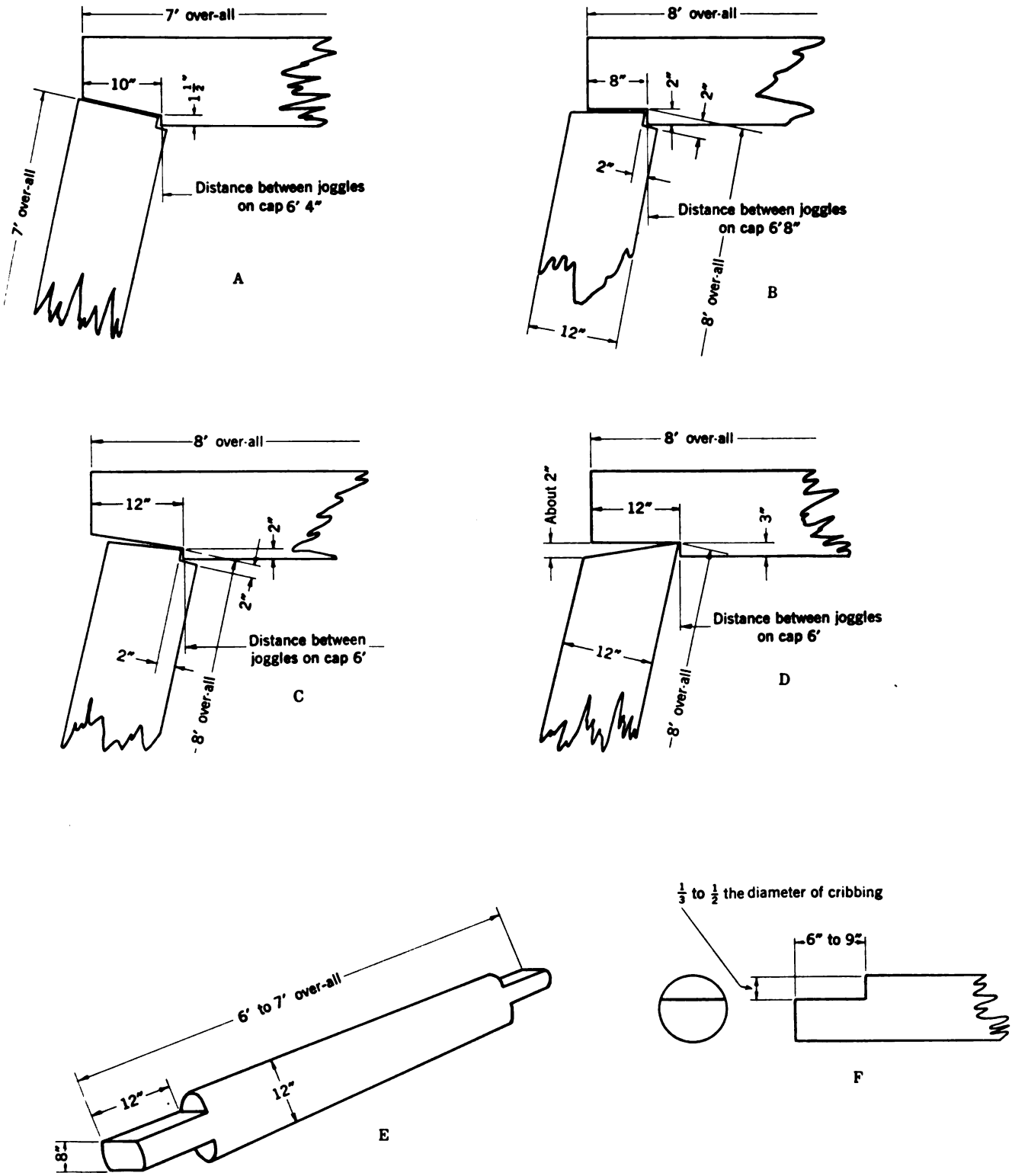

Figure 3. - Mine timber framing details.

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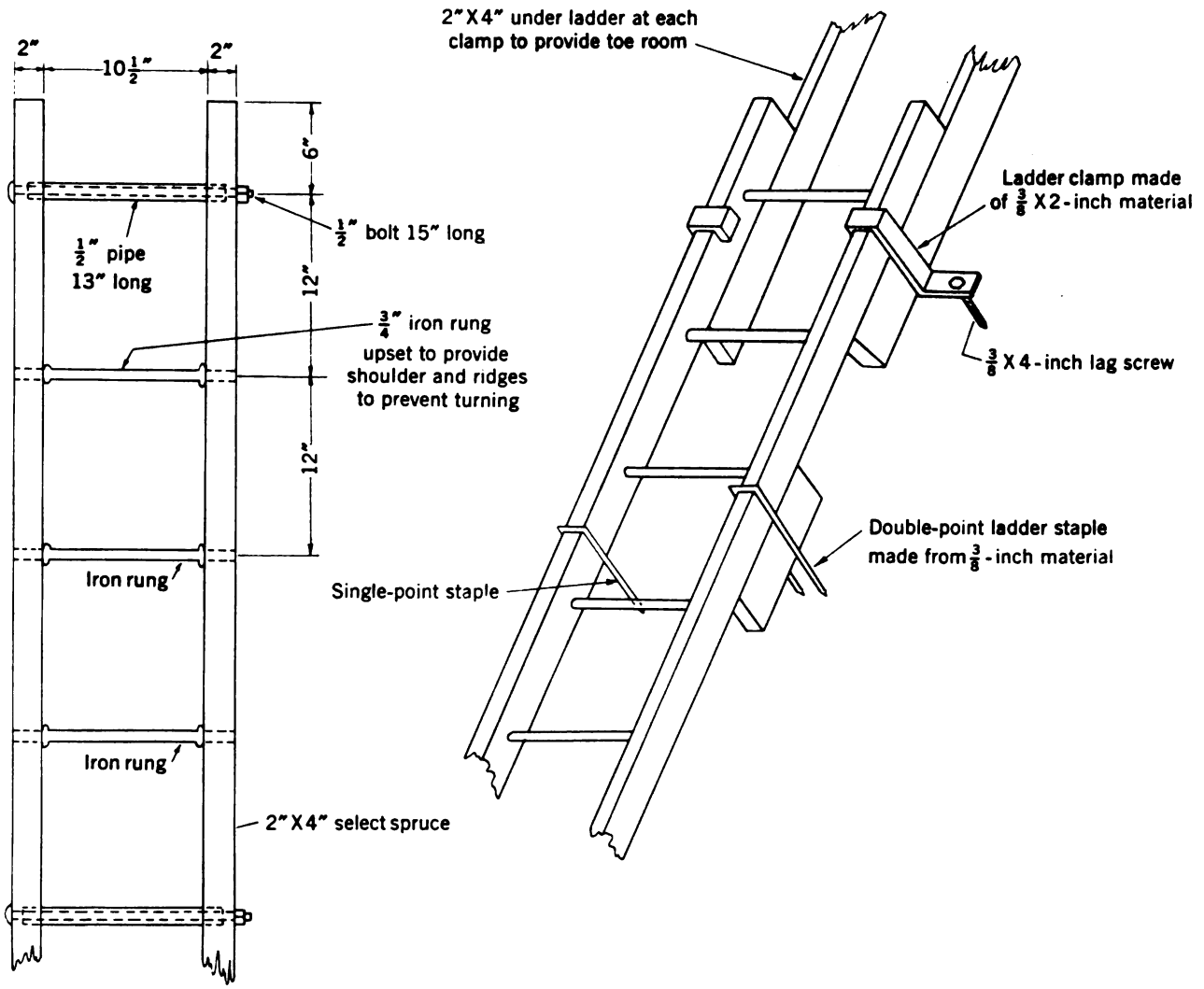

Figure 4. - Ladder construction.

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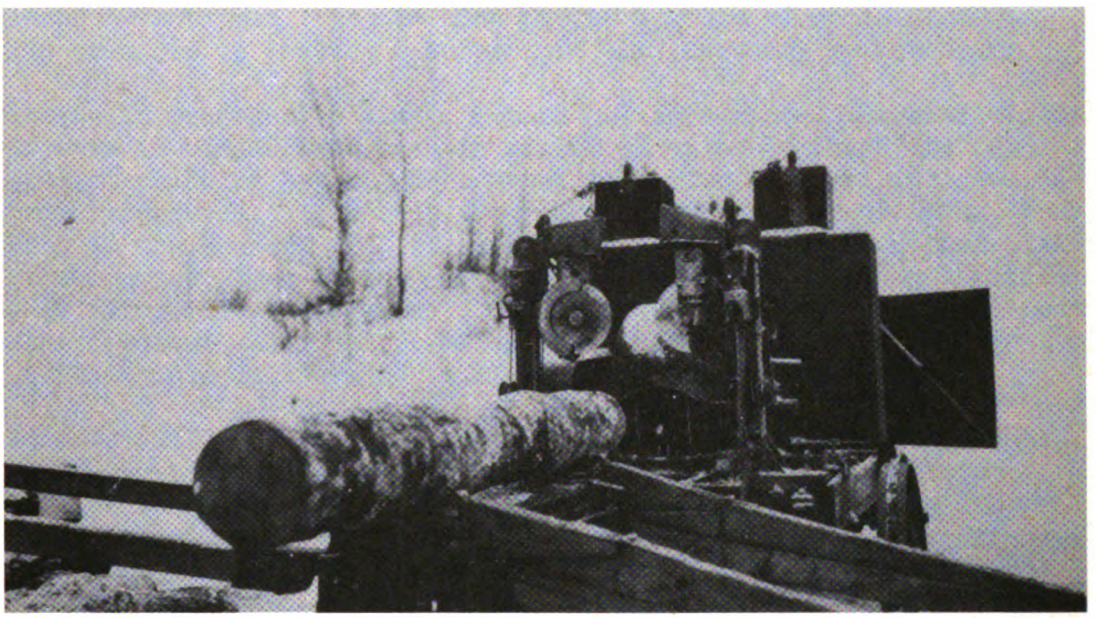

Figure 5. - Power saw for framing cribbing.

Figure 6. - Portable timber-loading derrick.

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Batter on the posts varies according to ground conditions and the severity of side pressure. In the relatively shallow Minnesota mines there is little side pressure and posts are set from vertical to a batter of 12 inches in an 8-foot post. In one mine on the Gogebic range in Michigan, where side pressure is severe, a batter of 3-1/2 feet may be necessary.

Cribbing is practically always framed on the surface. Several mines use power saws in conjunction with an adz or an ax to do this job. At one mine a special cribbing saw has been developed. Two parallel rip saws, set at the proper interval, slice back the rounded edges of the cribbing, leaving a tenon in the center. Two crosscut saws, operating on vertical slides, cut off the rounded edges at the bottom of the tenon, completing the framing. This saw is illustrated in figure 5. Other mines use a standard table saw to make the crosscut and complete the framing with an ax. The two types of framing cribbing are illustrated in figure 3 (E and F).

Ladders usually are made in the surface carpenter shop. Runners are commonly 2- by 4-inch or 2- by 6-inch select spruce, hemlock, fir, or tamarack. The lengths ordinarily used are 8,12, and 16 feet, the latter being cut in half to make two 8-foot lengths. The rungs are most frequently made of 3/4-inch iron, but they may be 5/8- or 7/8-inch iron. One company uses 1-1/2-inch oak rungs. Distance between rungs is either 10 or 12 inches, and the space between runners ranges from 10 to 12 inches. Construction of ladders and methods of mounting are illustrated in figure 4. Where power tools and complete shop facilities are available, 2 men can make as many as 36 ladders in 1 shift.

Transportation and Handling

Timber yards generally are located at a convenient point near the shaft with a sufficient distance intervening to minimize the hazard to underground workings from fire and smoke. Timber may be transported from the yard to the shaft in several ways. Where the shaft cage is large enough to accommodate mining timbers in a horizontal position, the mine track is extended to the yard and timbers are loaded directly on mine timber trucks. This is the usual practice at Lake Superior district mines. If the shaft cage is small, requiring the timber to be placed upright on it, transportation from the yard to the shaft may be by sled, wagon, or autotruck. One mine (K) with a small cage chains the timbers to a regular mine-timber truck and upends the truck on the cage by use of a slusher hoist.

A number of mines provide "timber tunnels" from the yard to the shaft. These are usually a combination of snow shed and tunnel connecting with the shaft at a point just below the collar. They are provided because of snow conditions and severe winter weather. In the timber yard the track level of the "tunnel" is far enough below the ground level to allow timbers to be rolled onto, rather than lifted on the trucks.

One mine uses a portable timber loader in the yard. It consists of a small derrick and slusher hoist mounted on a truck, illustrated in figure 6.

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While timber is being lowered into the shaft, one crew loads the cage at the surface and another removes the timber on the level. No one is allowed to ride the cage with timber.

In shallow mines on the Mesabi range in Minnesota, a special timber shaft is sometimes provided. This is usually a one-compartment shaft, timbered and lined with plank. Timber is lowered in chained bundles by a hoist on the surface.

The amount of timber stored underground is limited by available space and resulting fire hazard. Usually a 1- to 2-day supply is stored underground, mostly in the individual working places, or en route. Some mines have shaft stations large enough to accommodate a number of loaded timber trucks; one mine provides a special timber crosscut off the shaft for storing the trucks. In other mines the timber is hauled directly to the working faces.

Although timber storage on a main level is not a desirable practice, this may, in some instances, be impossible to avoid. Figure 7 illustrates a convenient method of piling poles and lagging between uprights and the drift posts. Caps and posts are piled on the opposite side of the drift on cross timbers.

Some mines provide an intermediate timber sublevel between the main levels. The timber sublevel may connect with the main shaft, or timber may be lowered to it through an incline. This practice separates timber-handling and ore-haulage activities and provides additional storage room. A further advantage is reduction of the distance which timber must be hoisted or lowered.

Timber is hoisted or lowered from the main level or timber sublevel to the working sub by air or electric-powered timber hoists, or by using the slusher hoist. A timber "boat" or "basket" is frequently provided, but slings and half-hitches are sometimes used. Timber hoists are commonly located at the tops of raises to avoid a return cable in the raise, which may cause trouble with the load being hoisted.

The raises through which timber is handled usually are lined with plank to provide a smooth surface for the load to slide on. A door covering the raise is commonly installed at each working level. As a further precaution, some mines install safety gates at regular intervals. These are made of small poles and are hinged on the hanging-wall side of the raise. Figure 8 is a view looking down a raise showing a safety gate. The gate is installed at a small angle with the axis of the raise, so that a load of timber being hoisted will push the gate open and will fall back into place when the load has passed through. The cable can be slid down along the footwall, passing through the slot in the gate, for the next load. Obviously, such a gate cannot be used in connection with a timber boat. Where timber boats are used, gates are provided at each sublevel which must be opened before timber is hoisted and closed afterward.

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Figure 7. - Timber storage on main level.

Figure 8. - Safety gate in timber-supply raise.

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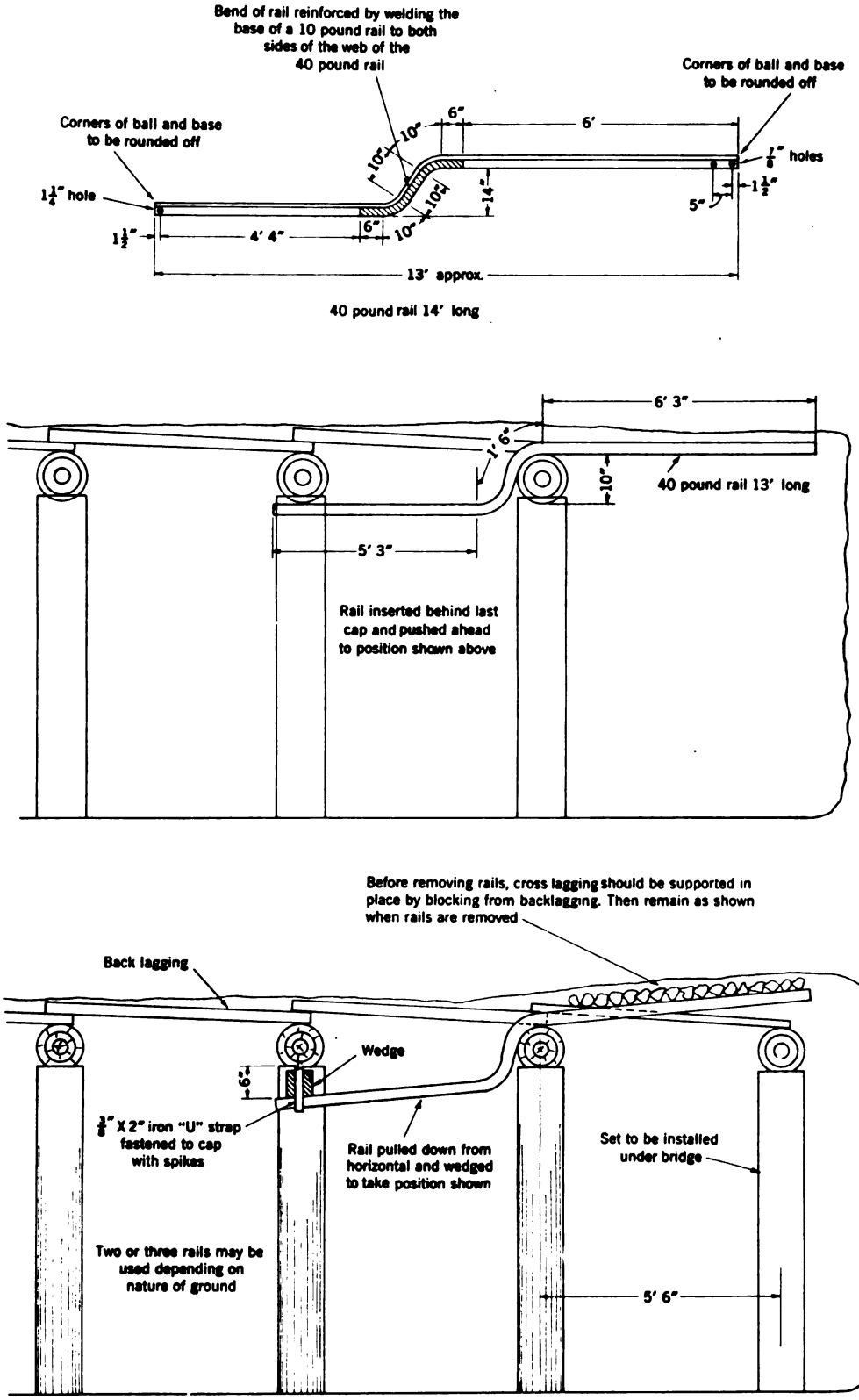
Bend of rail reinforced by welding the base of a 10 pound rail to both sides of the web of the 40 pound rail
Corners of ball and base to be rounded off
Corners of ball and base to be rounded off
6"
6'
10"
10"
10"
14"
7/8" holes
1 1/2"
5"
1 1/4" hole
1 1/2"
4' 4"
6"
10"
13' approx.
40 pound rail 14' long
6' 3"
1' 6"
10"
40 pound rail 13' long
5' 3"
Rail inserted behind last cap and pushed ahead to position shown above
Before removing rails, cross lagging should be supported in place by blocking from backlagging. Then remain as shown when rails are removed
Back lagging
Wedge
6"
3/8" X 2" iron "U" strap fastened to cap with spikes
Rail pulled down from horizontal and wedged to take position shown
Set to be installed under bridge
Two or three rails may be used depending on nature of ground
5' 6"

Figure 9. - Details of construction and installation of safety rails used as forepoles to provide overhead protection during timbering.

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A signaling system between the bottom and top of the timber raise is generally provided. It may be a speaking tube, battery or low-voltage buzzer, flashing light, or air whistle operated by a pull cord. Audible signals are preferred for obvious reasons.

Timber is hoisted either by the miners themselves or by timber handlers who deliver the timber to the working sub. Usually the slusher hoist is used to pull or skid the timber to the face.

Red lights are provided to stop haulage trains and warn motormen when timber is being hoisted from a main level. No one is allowed to pass under raises where timber is being hoisted, and if it becomes necessary to enter the raise to free a load, this must be done from above.

Timber storage near the working face is not desirable from a good-housekeeping standpoint; however, a certain amount is unavoidable. Ordinarily; not more than one set is on the working level at one time.

Installation

Accidents from falls of ground occur most frequently when miners are exposed to unsupported backs. Thus one of the most hazardous periods of the mining cycle is between the time of blasting and installation of the new set of timber. To reduce this hazard, most mines require the installation of forepoles with cross lagging to provide overhead protection during actual installation of every set. The basis of this requirement is sound reasoning - if the ground requires timbering, miners should not at any time be exposed to unsupported backs.

Forepoles are installed as soon as practical, usually immediately after barring down. Barring down is a hazardous task and should be done with a bar from under protection of the timber. Frequently it is necessary to scrape out part of the broken material to bar down and place the forepoles.

Forepoles are commonly 4- to 6-inch green tamarack or maple, 8 to 12 feet long. They are installed over the last cap and tailed under the preceding one or blocked up to the lagging between the sets. Some mines provide hitches in the face to receive and support the forepole, which increases their carrying power considerably. These hitches may be large auger holes drilled from under the protection of the timber.

A few mines use 30- to 60-pound steel rails to supplement or replace the wood forepoles. Figure 9 shows the construction and use of a special set of rails used by one company. Another company reinforces the wood forepoles with two or more 4-inch H-beams instead of rails because of the danger that the more brittle rails will snap under sudden pressure.

At least one company has gone even farther to protect the miners during timbering. In addition to the forepoles and lagging to support the back, sidepoles and lagging to support the sides of the opening are required. This procedure was incorporated into the safety rules when a study of the

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accidents due to falls of ground showed that numerous miners were being injured by falls from the sides of workings. Forepoling and sidepoling are illustrated in figure 10.

In some cases, the installation of forepoles may be difficult owing to caving of the back immediately after blasting. In this instance it is necessary to force or drive the forepoles into position before the broken material is removed, otherwise the back would continue to cave, causing a large area of broken ground above the working place.

A device that has been successful in forcing forepoles through caved material is illustrated in figure 11. It is an extra-heavy piece of 6-inch pipe about 20 inches long. A 6-inch sheave is mounted in a slot cut in one end of the pipe. The other end receives the forepole, which seats against a 2- by 3/4-inch piece of iron secured in the pipe at about midsection. The slusher hoist provides the power to push the pole into position, using the pull rope as indicated in the figure. A double-block arrangement is sometimes used where more power is required.

Where it is known that the backs of workings are likely to cave after blasting, the time of blasting is arranged so that the installation of forepoles will not be delayed, such as over a week end or over night.

At some mines, drifting operations run into difficulty where the material is water-saturated and sufficiently soft to "flow" after blasting, sometimes filling the drift for as much as 50 feet. To avoid this situation one mine has, on occasions, placed the forepoles prior to blasting the round. This is accomplished by placing the forepoles in 5-inch holes, drilled with special auger steel. Another mine uses 10 or 12 2-1/2-inch iron bars placed in drill holes around the arch of the working. These procedures are tedious, but in difficult ground the eventual time saved warrants the practice.

Once overhead protection is provided, the broken material is scraped out and timbering started. Posts are usually erected by hand, although some mines use the slusher rope and a block to pull them into a standing position. Posts may be held in place temporarily by the slusher rope or by a special brace until the angle studdle and lacing pieces to the previous set are placed (fig. 12).

A staging is usually provided before the cap is lifted into position. Many types of stagings are in use. One mine uses metal stage horses which are easily and quickly placed and do not rely on attachments to the timbers. Others use "bridle poles," illustrated in figure 16, to support the stage planks. Still other mines use angle irons or metal straps instead of poles. One mine uses a suspended staging, illustrated in figure 13. This arrangement provides an intermediate resting place when lifting the cap into position. Another mine uses grab chains and hooks on each of the four posts, with two 8-foot, 20-pound rails on each side of the drift to support the stage planks, (fig. 14).

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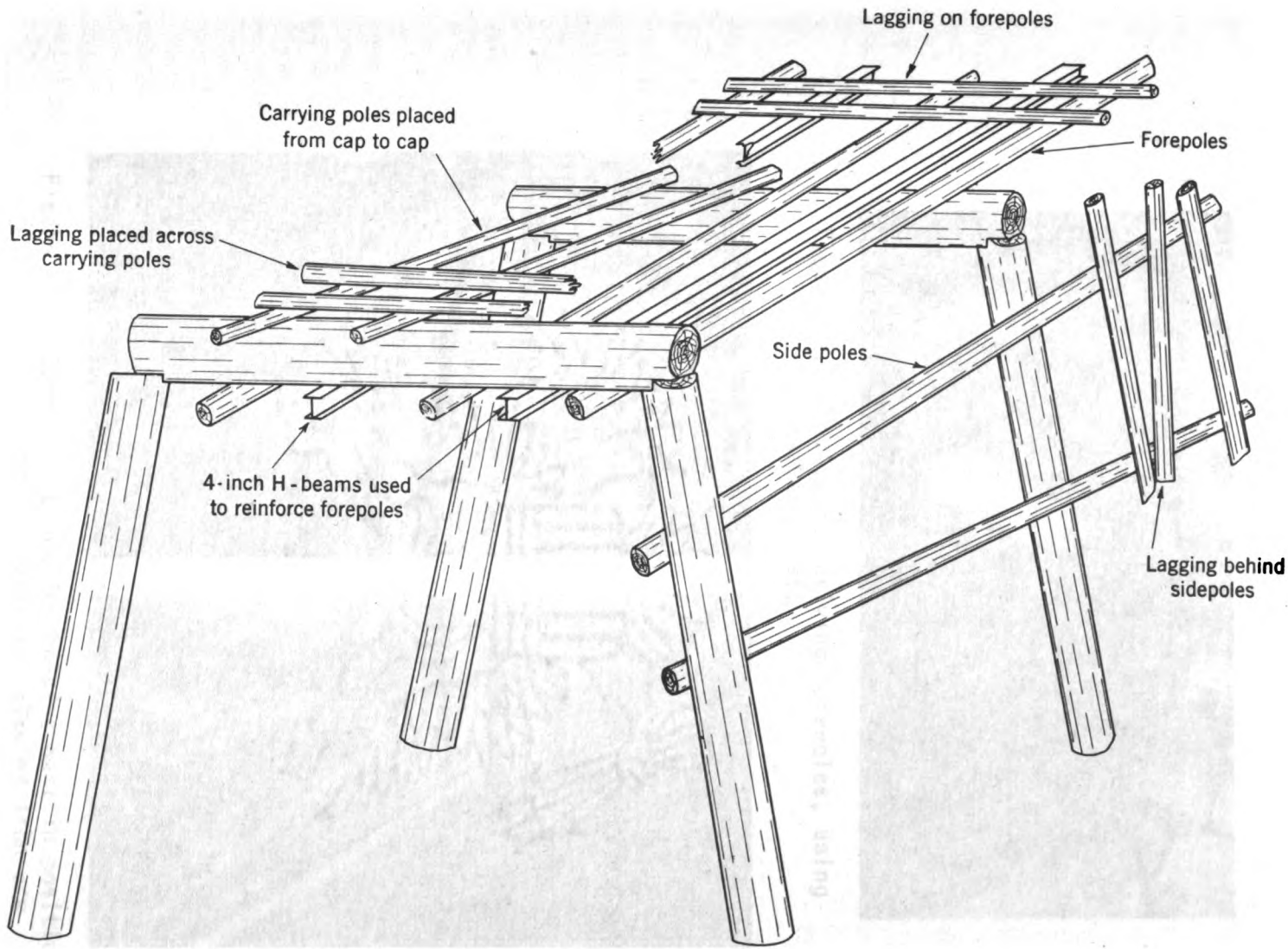

Figure 10. - Sketch showing method of placing forepoles, sidepoles, and lagging to provide protection during timbering.

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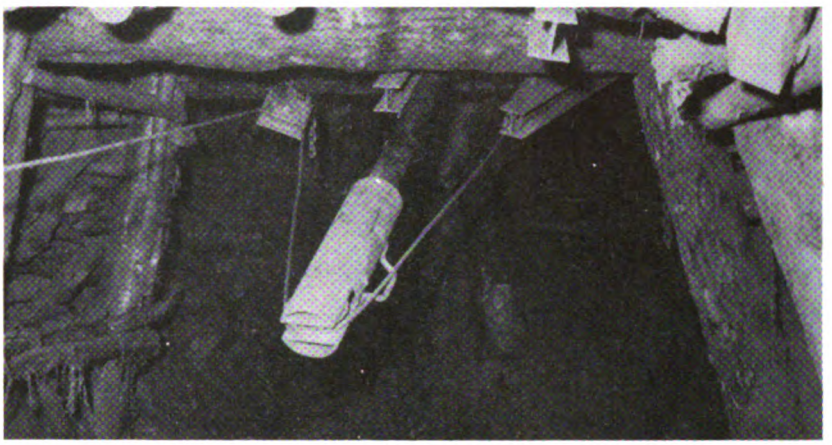

Figure 11. - Device for driving forepoles, using slusher hoist.

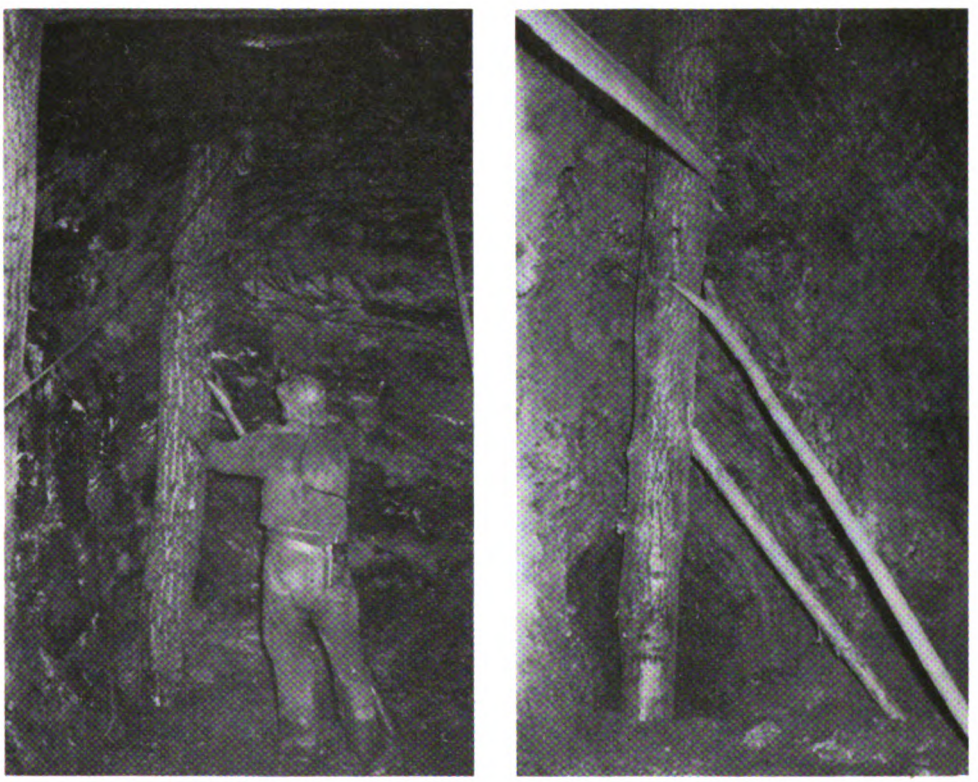

Figure 12. - Temporary brace for holding post in position while angle studdle and staging iron are placed.

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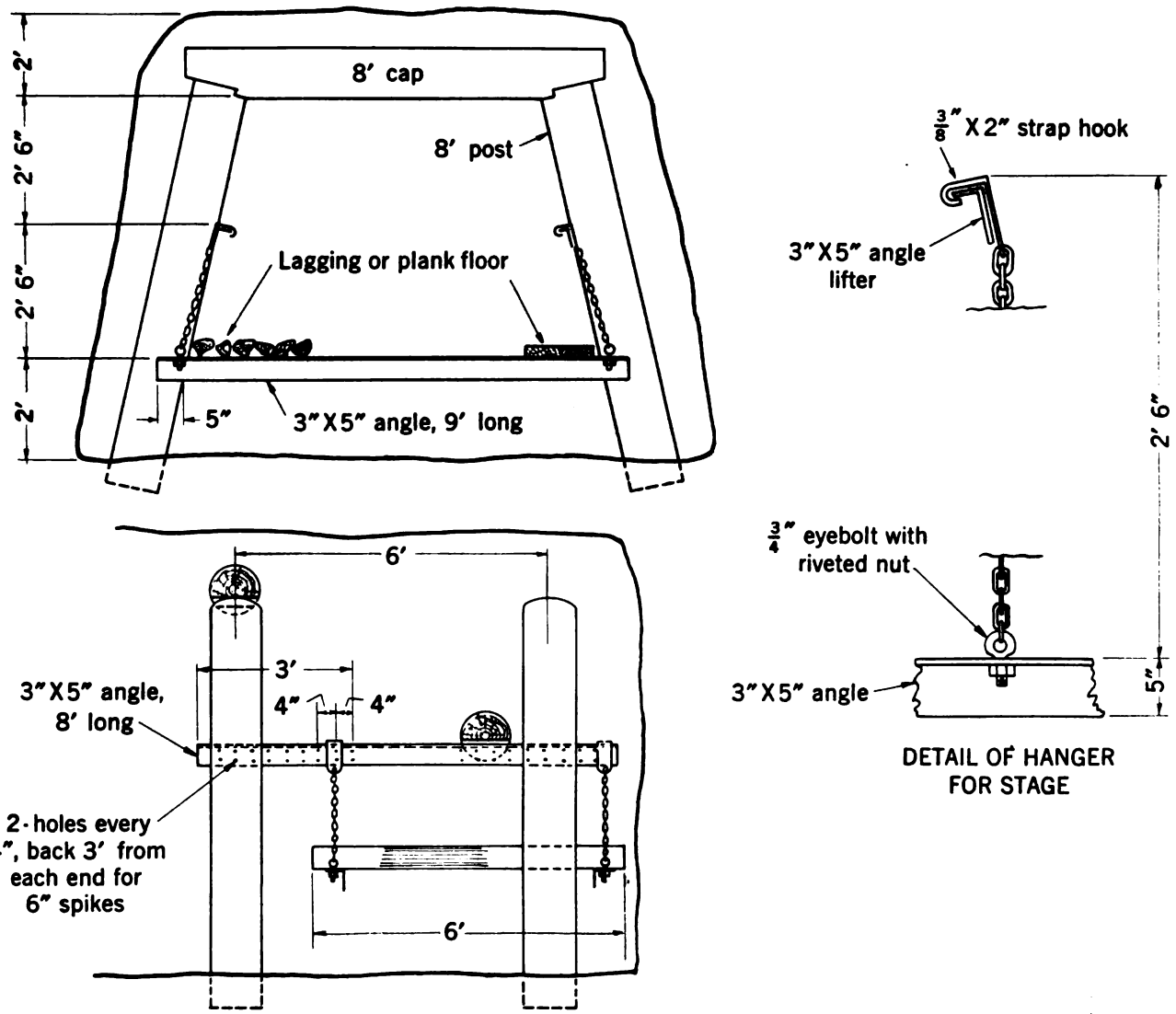

Figure 13. - Suspended staging used during timbering.

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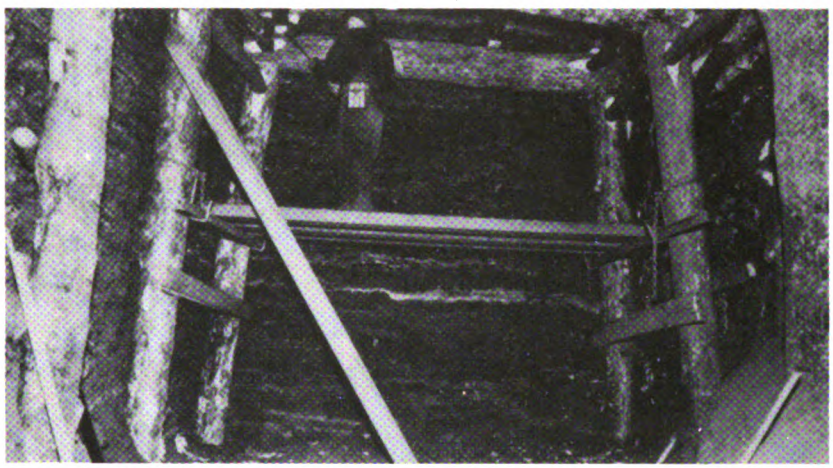

Figure 14. - Staging supported by clamps on post.

Figure 15. - "Covering down" floor of slice preparatory to blasting down slice.

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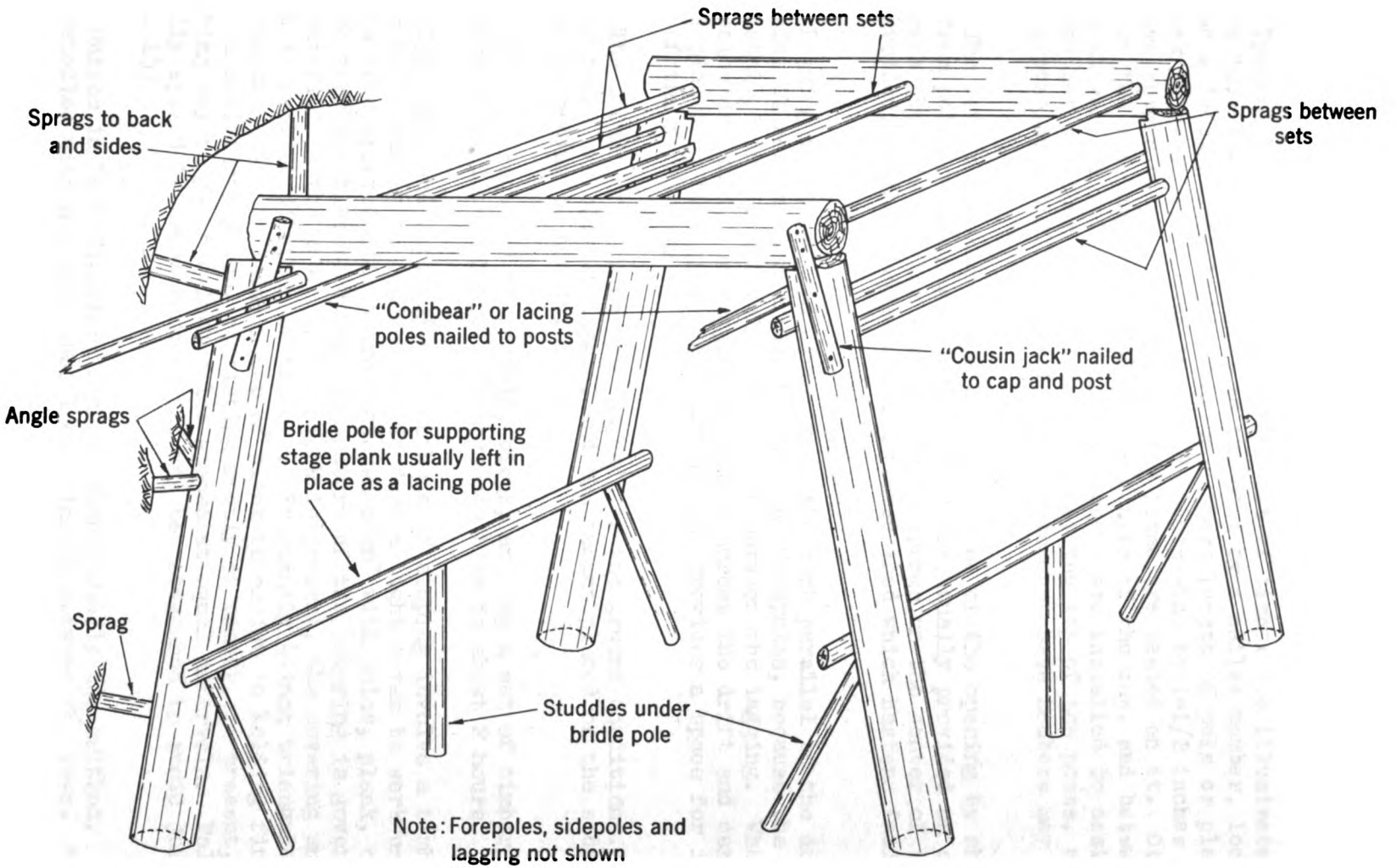
Sprags between sets
Sprags to back and sides
Sprags between sets
"Conibear" or lacing poles nailed to posts
"Cousin jack" nailed to cap and post
Angle sprags
Bridle pole for supporting stage plank usually left in place as a lacing pole
Sprag
Studdles under bridle pole
Note: Forepoles, sidepoles and lagging not shown

Figure 16. - Sketch showing blocking, lacing, and spragging of typical timber set.

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Stage planks are commonly 3-inch select fir or tamarack, 8 to 12 feet long.

Typical blocking and lacing of a set of timber are illustrated in figure 16. The cap is secured to the post by a nailed member, locally called a "cousin jack," which may be a short length of pole or plank. If a plank is used, it is usually 6 or 8 inches wide by 1-1/2 inches thick, and the two sprags between the sets at the frame are seated on it. Other sprags between the sets may be placed at the center of the cap, and between the posts at various points. Two nailed members are installed to assist in holding the set together - the lacing poles at the top of the posts, and the bridle pole near the bottom. In some instances these members may be plank.

The set is blocked to the back and sides of the opening by short sprags cut from poles or lagging. Angle sprags are usually provided on each post to brace the set. If the back is heavy, sprags on the center of the cap are avoided, as this causes a concentrated load which hastens failure of the cap.

Lagging may be placed directly on the caps parallel to the drift. This practice is common where rails are used as forepoles, because the rails can be installed in a relatively small space between the lagging. Where wood forepoles are used, the lagging is placed across the drift and carried on poles placed on the caps. This arrangement provides a space for installation of the forepoles.

The amount of lagging used depends on the ground conditions. Ordinarily the backs are closely lagged, and the amount placed on the sides varies widely according to conditions.

The time required to install, block, and lag a set of timber was reported to be 1 to 3 hours. The average time is about 2 hours.

Top-slice and sublevel-cave methods of stoping involve a timber gob under which mining is conducted. To form a tight cover to work under, the floors of completed slices are "covered down" with poles, plank, or slabs before they are blasted down. The nature of the covering is governed by the material in the gob. If fine rock is present, the covering must be tight to prevent dilution of the ore. Frequently 4-inch triangular or diamond-mesh wire is laid on top of plank to assist in holding fine material. Where a satisfactory gob, consisting mostly of timber, is present, the covering may be 3- to 6-inch poles spaced at equal intervals. Poles are usually spiked to cross members and may be staggered to avoid joints (fig. 15).

Raises in Lake Superior iron-ore mines usually are cribbed. Cribbing is installed with not more than 1 or 2 inches between the rows. Ordinarily two sets of single cribbing are used to make a double-compartment raise. Cribbing is installed without nailing, except for the last row or two before a cut is blasted. Cedar lagging is used to block the cribbing to the sides of the opening.

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Cribbed raises are sometimes completely lined with hardwood plank if they are to be used as ore passes and planked on the bottom and part way up the side if used as a supply raise. Lining may be double plank; and if abrasion is severe, it may be reinforced with strips of sheet metal. Lining planks may have holes drilled to receive the nails, especially if the hardwood planks are dry.

Failure and Repair

The two most common causes of mine timber failure are decay and pressure. In general, timber failure in main levels and workings of a more or less permanent nature is due largely to decay. In working slices where the loads on timbers are relatively great, failure is due mostly to pressure, although decay may be a contributing cause.

The rate of decay of timber depends on the amount of moisture, temperature, ventilation, character of wood, and kind of fungus. Warm, humid atmospheres, which are common to most mines, favor rapid decay and subsequent failure. Good ventilation reduces the temperature and humidity and thus retards decay and failure.

Because of varying conditions and factors, it is impossible to compare the decay resistance of the various species of timber used in mining with any degree of accuracy; in general, cedar has the highest resistance to decay. The reason for its wide use as lagging in contact with the ground is obvious. Tamarack, although classed as having an intermediate resistance, is superior to the other varieties used in local mines. For this reason it is preferred for main levels, cribbed raises, and other main workings. Other species have approximately the same resistance to decay, being classed between the "intermediate" and "nondurable" groups.

Under conditions of use in Lake Superior district mines, the average life of tamarack is estimated to be 4 years. A few mines report the life of tamarack to be as much as 10 years. Other timber used is estimated to have an average life of 2 years.

When timber shows evidence of weight and approaching failure, it must be reinforced with props, lining sets, or timber cribs, or the timber must be replaced if the place is to be kept open.

Props are additional posts placed under the cap, usually near the regular posts, but they may be under the center of the cap. Frequently a regular system of propping is followed, and props are set according to rule. For instance, in long slices the first timbers installed are almost sure to be heavily loaded as the gob settles down on them. Props placed before an appreciable amount of settling occurs are installed more easily and effectively. In this respect, time becomes an element of ground support. Figure 17 illustrates propping where back pressure is evident.

Additional caps and posts placed between the regular sets are called "lining sets". They are commonly used to reinforce main-level timbering,

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Figure 17. - Timbering in a top slice, showing method of placing posts where pressure is severe.

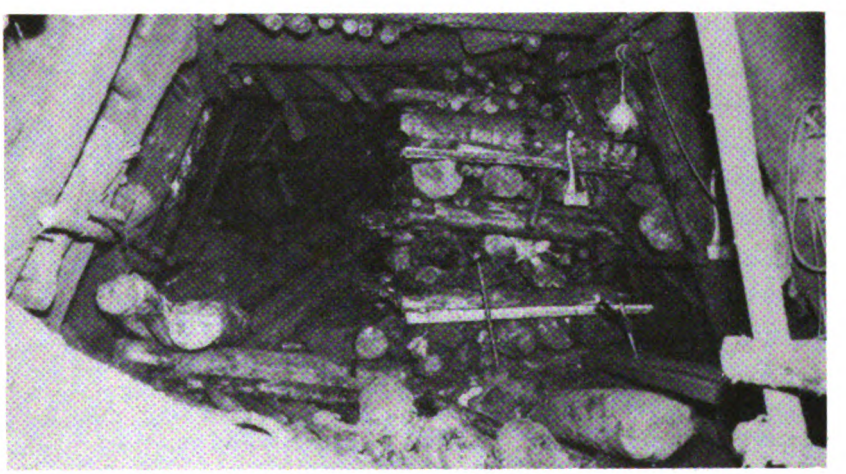

Figure 18. - Timber crib in top slice for support of heavy ground.

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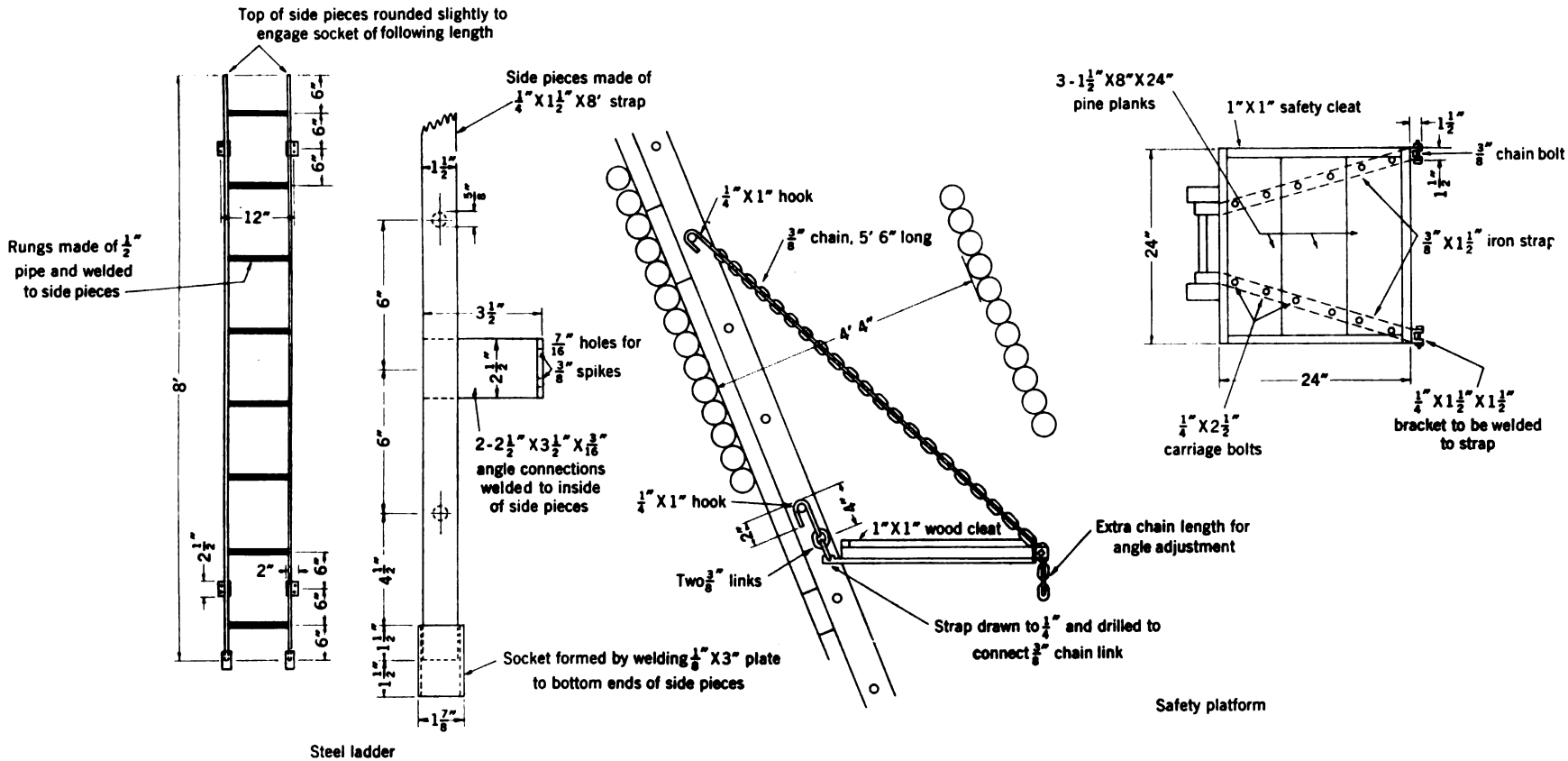

Figure 19. - Steel ladder and movable safety platform used for cribbed-raise repair and lining.

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because they maintain the clearance. In heavy ground several lining sets may be placed between each two sets, until the timbers are skin to skin. Further repairs must then be replacement of the original timbers. This is slow and tedious work. Old timbers must be cut out and room made for the new. Loose rock, as well as the need for maintaining traffic, usually complicates the work. The time required to replace a set ranges from 8 to 16 man-hours. Lining sets are usually erected in an hour by two men, if placed in time.

Cribs are used where weight is so severe that the place cannot be supported by conventional timbering. The cribs are usually constructed of cull or salvaged timber laid in alternately crossed layers. They are one of the most effective means of artificial support for heavy ground. Their principal use in this district is on sublevels at top-slice mines, to support the gob in the vicinity of the raise as mining on the particular sub approaches completion. The cribs are frequently placed in the openings of completed slices, or they may occupy half of a drift opening (fig. 18).

Cribbed raises require repair when the amount of material passed through wears out the lining or when the life of the raise exceeds the life of the timber. For raise repairing, it is a common practice to provide some form of a movable platform which fills most of the compartment. These platforms are usually attached to the ladder. A special steel ladder is installed and used for raise repair. Figure 19 shows such a ladder and a safety platform used for raise repair.

If the cribbing itself requires replacement, this is commonly done by starting at the bottom and working upward. If the cribbing has decayed or has been worn to a point where it will not support itself, such a procedure would be dangerous, and it is necessary to start from the top and work downward. A short section is repaired at a time, building the cribbing up on bearers placed across the raise. In some instances, in order to prolong the life of the raise for a short time, a single row of cribbing is replaced at definite intervals to which the new lining plank can be nailed.

Preservation

The preservation of mining timber has been practiced to a limited extent in the Lake Superior district for the past 20 years. On the basis of this experience, a reasonable estimate of the average life of treated mining timbers is 12 to 15 years. Comparing this with an average life of less than 5 years for untreated timbers, it is surprising that wood preservation is not practiced more widely. It is believed that too little attention is being paid to the known methods of prolonging the life of mining timber, such as proper storage, peeling, seasoning, and impregnation with a wood preservative.

Three plants for treating mining timber are now in operation in the district. A generalized description follows:

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Timber that is to be treated is usually cut and peeled in the spring, when the latter operation is most easily accomplished. Timber is then hauled to the mine, where it is allowed to season for 3 months to 1 year. Proper piling during this period to allow free circulation of air assists the seasoning process and retards the start of decay. Seasoning is necessary because the preservative cannot penetrate wet or green wood that is already full of water. Seasoning also produces checks on the surface of the logs which are avenues for the penetration of the preservative.

Timber may be framed before or after seasoning, but it should not be cut after treatment, because this would expose untreated surfaces.

Chromated zinc chloride (CZC) is the preservative commonly used. It contains approximately 18-1/2 percent of sodium dichromate, the remainder being zinc chloride. This is a relatively new preservative which has largely replaced the zinc chloride formerly used.

For sake of simplicity and economy, a nonpressure process, known as the hot- and cold-bath process, is used. It is the most effective of the nonpressure processes. Timber is soaked in hot water (about 210°) for 12 hours, during which time the air and moisture in the wood expand, and some of it is forced out. The timber is then immediately placed in a cold bath of 10 to 12 percent chromated zinc chloride. As cooling takes place, the air and water vapor in the wood contract, forming a partial vacuum which draws the preservative into the wood. About 3/4 to 1 pound of CZC is consumed per cubic foot of wood, and the penetration varies from 1/2 to 1-1/2 inches.

For ease in handling timber during the treatment, it is placed in racks or baskets holding about 12 caps or posts. A monorail crane or derrick is provided for lifting the racks. Tanks are large enough to hold either one or two racks of timber at one time. In the latter case, the tanks are long enough to accommodate 20-foot timber if necessary.

The hot tank is heated by steam coils or by bubbling live steam up through the water. The hot tank is insulated, and covers are placed over both tanks.

At one mine all timber treatment for the entire year is done during September. Each of the tanks hold two baskets of timber. In one day two men can treat 50 pieces and frame 35 pieces. The following costs are reported:

Cost of timber - 15¢ per linear foot.
Framing - 1 to 3¢ per linear foot.
Peeling (on contract) - 3¢ per linear foot.
Treatment - 4-1/2¢ per linear foot.

The same mine reports the cost of an untreated set of timbers, in place, to be $13.50 against a cost of $15.00 for treated timber.

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Another mine using larger timber reported the following:

Cost of one 8-foot piece timber, 16 inches in diameter.	$2.25
Cost of chromated zinc chloride used	.78
Cost of labor, coal, and other items.....	.82
Cost of peeling.....	.48

In this instance the treatment almost doubles the cost of the timber. However, considering that transportation and cost of installing the timber will be the same in either case, the advantage of using treated timber is obvious.

Steel and Concrete

The use of steel and concrete for the support of ground in shafts, shaft stations, pump rooms, and drifts of a semipermanent character is increasing. Steel lasts longer than timber, required less labor to install, and does not constitute a fire hazard. Less excavation is required for steel supports. On the other hand, steel is not always satisfactory for heavy or moving ground, it cannot be so readily cut and fitted underground, and the first cost is high. However, there is a definite over-all advantage in the use of steel, where conditions do not preclude its use.

The use of steel for shaft sets has been a standard practice in the Lake Superior district for many years. A few of the older shafts are supported entirely with wood. The first shafts supported with steel sets commonly had wood lath. Table 4 lists general information regarding six shafts in the district that are relatively new or recent.

The trend in shaft support is toward eliminating all wood to reduce the fire hazard. Previously wood lath was commonly used with steel sets, but recent practice is toward the use of heavy galvanized, stainless or rustless corrugated iron, or reinforced concrete lath. The wood used to block the shaft sets is being replaced by concrete. In some instances, steel sets are concreted around the full perimeter with a beveled pour to the shaft walls. In other shafts, cement sacks about half full of high-strength wet concrete are puddled or jammed into place behind the sets. This procedure is said to reduce shaft maintenance considerably.

The steel section most popular for shaft sets is a 6-inch H-beam. Vertical shaft studdles are commonly angle irons. Bearer sets usually are 12-inch I-beams, concreted into hitches in the walls.

Shaft stations and main haulage drifts are frequently supported with steel sets. Typical sections used are 4-, 5-, and 6-inch H-beams and 8- and 12-inch I-beams. Occasionally 30- to 80-pound steel rail is used. In a few instances, the use of 6- and 8-inch iron pipe was observed.

The selection of the proper size of steel for a given service is based on the strength of a steel section equivalent to that of a timber which

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experience has indicated necessary for that job. On this basis, one company uses an 8-inch I-beam where a 8-foot 16-inch timber would be used as a cap. The steel post required to carry such a load could be a 4-inch H-beam, provided there is no side pressure.

TABLE 4. - General information on shaft timbering

Shaft	Dimensions outside of steel	Wall plates (section)	Studdles (section)	Lath	Distance between sets	Blocking	Bearers
1	12'6" x 19'8"	6" 23.8# H-beams.	2-1/2" x 3-1/2" x 1/2" angles.	Reinforced concrete.	6'	Cement sacks of wet concrete.	Heavy I-beams parallel to plates.
2	13'1" x 18'7-1/2"	6" WF 25# H-beams	6"x6"x1/2" angles and 3-1/2" x 3-1/2"x1/2" angles.	No. 14 gage corrugated iron.	7'	Cement sacks of wet concrete.	12-inch I-beams at 160' intervals.
3	11' x 18'	6" H-beams.	4"x4"x3/8" angles.	3" fir plank.	8'	Wood blocks and wedges	12" I-beams at 100' intervals.
4	11'11" x 15'10-1/2"	7" 15# I-beams. 6" 14.75# I-beams for dividers.	6"x6"x1/2" angles	3" fir plank.	6'	Wood blocks and wedges.	10-inch I-beams.
5	12'4-1/2" x 15'6-1/4"	6" 20# H-beams.	6"x6"x1/2" angles.	3" fir plank.	6'	Wood blocks and wedges	12-inch I-beams at 150" intervals.
6	13'1-3/8" x 21'1-1/2"	6" 23# H-beams.	3"x5"x3/8" angles.	2" hardwood.	8'	Wood blocks and wedges	12-inch I-beams at 150' intervals.

Figure 20 shows the support of ground on a main haulageway at one mine, by steel sets fabricated in the local mine shop.

Steel sets can be installed in about half the time required for a conventional timber set. One disadvantage is that steel sets cannot be installed

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Figure 20. - Steel sets used for support on main level.

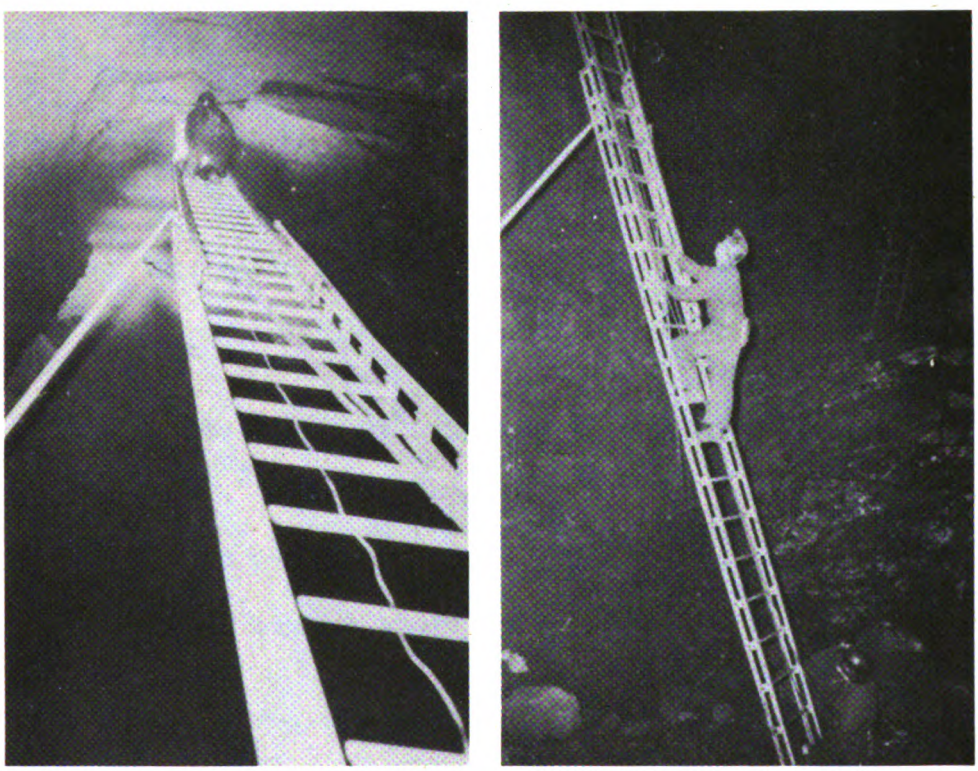

Figure 21. - Aluminum ladder, 3-piece extension, used for barring down in open stopes.

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close to a blast, without serious damage to the members. To overcome this, one company timbers places with conventional wood sets as a drift is advanced, and replaces them with steel sets at a later time. The steel sets are placed alongside the timber, catching up the lagging already in place. Wood posts and caps are then removed.

Barring Down

Failure to test overhanging ground adequately and to remove loose material is responsible for numerous fall-of-ground accidents. Other accidents occur during the actual barring down because of failure to use proper tools, or because of unsafe methods in the conduct of the work.

The following rules for testing and barring are quoted from Miners' Circular 41 (p. 10):

1. Use a straight, sharp bar of proper length.

2. Obtain secure footing in such a position that falling rock will not roll toward you.

3. Begin barring from a safe place, and make the back safe before advancing under it.

4. Guard against rocks sliding down the bar, and keep your end of the bar away from the body, so that a suddenly dislodged rock cannot drive it toward you.

5. When prying, raise up on the bar instead of pushing down.

6. Test all apparently loose material, whether or not it was tested on the previous day.

7. If rock sounds loose but cannot be barred down, support it with timber or blast it down.

8. Allow no one to pass under dangerous or "drummy" ground before it has been made safe, and warn all newcomers of unsafe conditions.

9. Use particular caution where there are slips, a "change of ground", or water seepage.

10. Test the back frequently while drilling.

11. Test all suspicious-looking rock or ground. Loose rock may or may not produce a "drummy" or hollow sound; if it does not, sometimes vibrations may be felt with the fingers or with additional rod or bar held against the questionable rock, while tapping it with a bar or rod.

12. Keep the muck pile well-sloped, and bar down any boulders that may be lodged at the top of the slope.

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Bars used for trimming loose ground are usually made of solid steel 1/2 to 1 inch in diameter in lengths of 5 to 8 feet. Longer bars are made of pipe with a solid steel point to reduce the weight. Good practice prohibits bars with points on each end for obvious reasons. A few mines specify the length of bar to be used in a particular operation, and the use of a pick for removing loose ground is discouraged.

In drifts and mining slices where loose ground must be barred down prior to installation of forepoles, the job is particularly hazardous and requires extreme care. Safe practice requires that barring be done from under the protection of the existing timber, but too frequently miners expose themselves to an unsupported back and remove the loose material with a pick. Frequent accidents are evidence that the practice is unsafe.

In open stopes where the backs are high, barring down is difficult and hazardous. Long ladders are used, and only expert barmen are assigned to this work. One company uses a 3-piece aluminum ladder which can be extended to a height of 60 feet. It is equipped with two aluminum braces and can be easily set up by two men (fig. 21). Stopes are barred down as frequently as inspection shows necessary. A portable high-powered floodlight is used during the inspection.

SAFETY RULES PERTAINING TO GROUND SUPPORT

The most effective method of preventing accidents due to falls of ground is the establishment of safe procedures for conduct of the work and close supervision to see that they are followed. Safety rules are based on past experience, usually unfortunate and disastrous experience in which miners were injured or lost their lives. Unfortunately, too many remedial measures are taken after lives have been lost. The following safety rules are quoted, to assist others to profit by the experience on which they were based.

COMPANY X

Mining

General

1. All necessary precautions shall be taken to insure the safety of the timbering in a mine.

2. Sets of timber shall be securely laced when erected.

3. Forepoles reinforced with two or more H-beams, minimum size 4-inch, or 10-lb. to the foot, shall be used between the last set of timber and the heading when there is ore or rock in the back.

4. Wherever possible gin poles or sprags shall be kept between cap of last set of timber and the breast until the succeeding set has been securely blocked and spragged.

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5. Not less than two sound poles shall be used to support the sides of an advancing ore drift or slice.

6. Only sound fir or tamarack planks not less than 3 inches thick and 8 inches wide shall be used for staging when lifting caps.

7. Bridle or stage poles shall be of sound tamarack not less than 3 inches in diameter at the small end. These bridles shall be supported at both ends and in the middle by studdles, not less than 3 inches in diameter at the small end. The ends of the studdles shall be cut to furnish maximum support, otherwise bridles of angle iron 3 by 3 by 1/4 inch shall be used, and these shall be supported by not less than two studdles placed at each end.

8. Where two slices are open, one slice shall be blasted down before a third slice is started.

9. Every contract shall be provided with a ladder about 8 feet in length to be used for handling head blocks and for cleaning loose ground from caps, sides, or back.

10. Timber and rope hooks of approved patterns shall be used by all men landing timber at the top of raises.

11. A bar at least 7 feet long, to be used for trimming loose ground, shall be furnished each contract.

Timbering

1. Timber sets on sublevels shall not be placed more than 6 feet from center to center.

2. Legs of timber sets may have batter of not more than 2-1/2 inches to the foot, except in ground with heavy side pressure, where it may be increased to 3-1/2 inches to the foot.

3. In top slicing, the bottoms of the timber legs of the new slice shall be placed within the line of the bottoms of the legs of the old slice so as to reduce the space to a minimum.

4. In heavy ground no timber under 10 inches in diameter shall be used for legs or 12 inches for caps.

5. Scraper hoists may be used to hoist caps to the staging, but not to position on top of the legs. Everyone shall stand in a safe place when timber is being hoisted.

6. In pulling timber with a scraper hoist men shall stay at least ten feet back of the moving timber.

7. White birch, beech and hemlock must not be used for caps.

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Stopes

1. After blasting in a stope both miners shall return together when inspecting it.

2. The back of benches shall be kept trimmed and arched to a height that will provide protection and also enough headroom for upright walking.

Sublevel Caving

1. When drifting, back holes shall be kept as near horizontal as possible so as not to weaken the back.

2. Drilling of blast holes shall be done only from under protective covering.

Top Slicing

Sublevel Interval

1. The maximum vertical interval between sublevels using 8-foot legs and caps shall be 11 feet and on sublevels using 9-foot legs with 8- or 9-foot caps shall be 12 feet.

2. The interval shall be timbered so that the mat can be caught up from the caps of the sets on the operating sublevel.

3. Where there is an unusually good mat due to a number of sublevels coming vertically under each other, the interval, with consent of the superintendent and approval of the manager, may be increased to over 12 feet, but the length of legs shall also be increased by the same amount.

Covering Down

1. Only sound poles 3-1/2 to 6 inches in diameter, plank or slabs not less than 2 inches in thickness shall be used as covering. Not less than two crosspoles, and preferably three, shall be used under the covering, which must be spiked to the two end crosspoles. Where necessary wire fencing of an approved type shall be used on top of the covering.

2. In territory with a good timber mat, the covering shall be laid lengthwise of the drift on top of the crosspoles to which they must be spiked.

3. Adjacent to dikes and areas of jasper, the covering shall be laid close together and extend tight against the breast. Each length of covering shall sidelap for half of its length and on curves overlap at least 12 inches. Wire fencing shall be laid on top of the covering and additional poles, lagging or old timber laid on top of the netting to build a mat quickly. If the ground in the back does not cave, it shall be blasted for filling after having covered down in the above manner. Only sound planks, slabs or poles shall be used as covering.

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Wire Fencing

1. When placing wire fencing, it shall be laid lengthwise in the drift and fastened with staples to the covering. One section of the fencing shall extend up on the legs at the side of the drift far enough to permit bending down or cutting at the legs to cover between slices.

Recovering of Pillars

1. If a pillar is left on a sublevel its locations shall be shown and labeled on the maps of the sublevel below and furnished the captains and bosses.

2. In case of a pillar left on the sublevel above, the first drift on a new sublevel shall be driven under it where practical.

COMPANY Y

Mining and Timbering

Stoping

1. Stopes which have given a warning of weakness must be inspected frequently by the foremen.

Trimming down

1. Special care must be given to trimming down back and sides of all openings, particularly after each blast.

2. Rock drifts should be inspected frequently and all loose and crumbling material removed from sides and back.

3. When bad pieces of loose ground are found, they shall be taken down at once and not left for the other shift.

4. No one shall work under any ground which cannot be reached with a trimming bar.

5. Benches shall be examined for loose ground, cross fracturing and slabbing underneath.

6. Every precaution should be taken around top of mills which have hung up and do not show location of raise.

Retimbering

1. The back of retimbering jobs shall be made secure so there will be no danger of ground falling on workmen passing underneath.

2. While retimbering over live circuit, trolley wire shall be covered by a piece of split rubber hose or rubber safety shield.

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Timbering in Soft Ground

1. Whenever timber is being used, the miners must be required to secure the roof of working place by forepoling. Props and head boards should be used where poles cannot be inserted.

Stagings

1. Staging planks not less than 2 inches in thickness must be used in all cases where staging is necessary.

Traveling Ways

1. Traveling ways to be kept free of drills, pipes, timber, etc.

Tool Slides

1. Tool slides shall be provided where practicable.

Safety Belts

1. Safety belts must be worn while drilling on benches in stopes and also while rigging or taking down drilling equipment on narrow benches.

2. Safety belts shall be checked monthly.

COMPANY Z

Raising

1. All raises over 25 feet in height, while under construction, shall have at least two compartments, one a "service compartment" for ladders, piping, service cage, etc., and one a "chute compartment" for broken material.

2. When men are working at the top of a raise or blasting, the service compartment shall be covered on the top of the last set of cribbing or stage poles, or at a reasonable distance below. The cover shall consist of at least a single course of 6-inch cribbing or 3-inch plank and shall serve as a working platform when men are at the top of the raise. A second platform shall be installed not more than 6 feet below the cover to serve as a safety platform.

3. Ladders shall be installed in the service compartment to the working platform as the raise progresses.

4. Inclined raises having continuous ladders shall have sollars not more than 25 feet apart. Vertical raises shall have staggered or offset ladders, supported on sollars not more than 15 feet apart.

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5. Just below the raise cover an opening shall be provided in the partition between the compartments to permit entering the heading after a blast.

6. A platform made of sound plank 2 inches or more in thickness shall be placed in the chute compartment opposite the entry through the partition. The platform shall be supported on stage poles or cribbing, and kept in place while men are working at the top of the raise.

7. All cross poles used for staging must be inspected after each blast and made secure before using.

8. Men working in a raise below the staging must wear safety belts at all times.

9. When a raise reaches a height of 50 feet, a suitable signaling device shall be provided.

Single Compartment Uncribbed Raises

1. Cross poles not less than 5 inches in diameter shall be placed midway in the raise at about 2-foot intervals, to support a temporary partition with which to divide the raise into two compartments--one a service and the other a chute compartment--each approximately 2-1/2 by 4 feet in size. The partition shall be made of plank or boards not less than 1 inch thick.

2. Cross poles, partition, and ladder are to be installed as the raise progresses. The partition should never be more than 8 feet below the top set of cross poles.

CONCLUSIONS

Although progress has been made in the reduction of accidents due to falls of ground in the Lake Superior district, the continued occurrence of such accidents shows that the problem is still a vital one. Too frequently men are injured or lives are lost in accidents involving violation of safe practices that are well known to both employees and supervisors. Such accidents are due to man failure and not to unsafe working conditions. It is the human element that is responsible for the bulk of the accidents.

Effective methods of ground support are well-known. Safe practices, which are a result of years of experience, are outlined in safety rules. It remains for well-directed safety programs to educate the miners until these common-sense precautions are taken as a matter of course. When safety becomes a habit, the human element in accidents, as well as the accidents themselves, will be further reduced.

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